Dusk emergence from den trees by the Wet Tropics Yellow-bellied Glider

Amanda Kaiwi[A], *Rupert A.W. Russell*[B], *John W. Winter*[C] and *Donald C. Franklin*[D]

[A]PO Box 105, Ravenshoe Qld 4888, Australia

[B]PO Box 63, Mount Molloy Qld 4871, Australia

[C]Threatened Species Program, Department of Environment and Science, 83 Main St., Atherton Qld 4883, Australia, and College of Marine and Environmental Science, James Cook University, 14–88 McGregor Road, Smithfield Qld 4878, Australia

[D]Research Institute for the Environment & Livelihoods, Charles Darwin University, Darwin NT 0909, Australia, and Ecological Communications, 24 Broadway, Herberton Qld 4887, Australia. Email: eucalypt@iinet.net.au

Abstract

Emergence of nocturnal animals at dusk from daytime shelters may be influenced by caution with regard to predators as well as by foraging opportunity and weather. Yellow-bellied Gliders (*Petaurus australis*) are a nocturnal, arboreal marsupial that, in north Queensland, den in hollows predominantly in large Rose Gums (*Eucalyptus grandis*). We document emergence on 83 evenings in the Tumoulin and Gilbey Forests between Ravenshoe and Herberton. Dens were high in Rose Gums, twelve from a lateral spout and, unusually, one from a hole in the trunk. The first glider to emerge from a den did so from 22 minutes before to 31 minutes after End of Civil Twilight (the latter being 21–24 minutes after Sunset in the study area and approximating dusk), though most first emergences were from nine minutes before to eight minutes after. First emergence was not influenced by moonlight, season or den tree, but varied a little between glider groups. Groups of gliders sharing a den variously emerged in quick succession or up to eleven minutes later. We describe other behaviours associated with emergence. This tight pattern of emergence at dusk is in line with reports for the species in southern Australia, but we document for the first time a number of associated behaviours including infrequent calling from within the den.

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Introduction

Nocturnal animals may delay emergence from day-time refuges until the risk of being sighted by predators is reduced. This yields the prediction that emergence may be delayed on evenings with bright moonlight. However, this timing may also be moderated by optimal foraging and social considerations, and moonlight may increase the ability of prey species to forage efficiently and detect predators. In a metanalysis of the activity of nocturnal mammals, Prugh & Golden (2014) found that moonlight increased the activity of mammals with high visual acuity but decreased it in those that primarily use senses such as smell or echolocation. Activity decrease was more marked in open habitats, and responses showed strong phylogenetic alignment.

The Yellow-bellied Glider (*Petaurus australis*) is an arboreal, nocturnal mammal weighing *c.* 550 g which dens in pairs or social groups in hollow trees (Goldingay & Jackson 2004). In north Queensland they usually den in large Rose Gums (*Eucalyptus grandis*) (Russell 1984; Goldingay & Quin 2004). Yellow-bellied Gliders usually emerge from dens within an hour after sunset or 30 minutes of dusk (Craig 1985; Goldingay 1989; Lindenmayer *et al.* 1991) with remarkably little variation within study areas. However, emergence may be deferred or they may remain in their dens all night if rainfall is heavy (Goldingay 1989; QEC 1991). The species was active for a smaller percentage of the night in winter than summer, but this occurred due to generally earlier retirement relative to sunrise in winter rather than variation in evening emergence (Goldingay 1989). In contrast, Mahogany Gliders (*P. gracilis*) emerged up to 80 minutes later relative to sunset on longer than shorter nights (Jackson & Johnson 2002). There are two previous general descriptions of den emergence for the as-yet undescribed subspecies of Yellow-bellied Glider endemic to north Queensland's Wet Tropics bioregion. Russell (1984) reported that "Den occupants emerged at dusk, not more than half an hour after sunset. They usually left rapidly, silently and in quick succession". QEC (1991) stated that they "left their dens at dusk, or shortly after" and delayed emergence during heavy rain. In this note we provide the first quantitative report of den emergence times of Wet Tropics Yellow-bellied Gliders, and describe some behaviours associated with emergence.

Methods

Observations

The Yellow-bellied Glider (Wet Tropics) (hereafter YBG) is confined to high-elevation moist sclerophyll forests with Small-fruited Red Mahogany (*Eucalyptus resinifera*) and usually also large Rose Gum (*E. grandis*) (Goldingay & Quin 2004). The former eucalypt provides sap which is periodically a key food item (Smith & Russell 1982), and the latter daytime dens for shelter though other tree species are sometimes used as dens (Goldingay & Quin 2004). This study was conducted in two such forests, Tumoulin (17°34'S, 145°30'E; *c.* 1,080 m ASL) and Scientific Area 44 within Bluff State Forest, and adjacent freehold, referred to locally as Gilbey Forest (17°27'40"S, 145°27'20"E; *c.* 1,060 m ASL), both between the towns of Ravenshoe and Herberton.

This study comprises three discrete sets of observations.

1. The first, with observations by AK, is a set over 27 evenings (17 with emergence(s), 10 without) from 19 July to 14 Nov 2013 at a single Rose Gum known as 'Spirit Tree' (Fig. 1) in Tumoulin Forest.
2. The second set comprises observations on 53 evenings (all with emergences) from 1978 to 1982 at four Rose Gums (Fig. 2) in Gilbey Forest by RAWR and colleagues. Observations span all seasons with a range of 8 to 16 observations per season.
3. The third set comprises 13 miscellaneous observations from seven den trees – all Rose Gums – in both Forests and by a range of observers.

In all three sets, emergence was observed by the stag-watching technique similar to that developed for surveying possums and gliders in structurally similar tall eucalypt forests in Victoria (Smith *et al.* 1989). Observers stationed themselves close to den trees (potential or known from previous observations) at about or before sunset. The number and species of glider emerging from dens were recorded, along with the date and time to the nearest minute.

At Spirit Tree, gliders were observed in natural light, with binoculars when required, and with a red-filtered spotlight when it became dark later in the evening. Observations were continued for at least 10 minutes after first emergence. Times were standard internet times obtained from a mobile phone or GPS unit and should thus be accurate. For these, prevailing weather conditions were also recorded: moon phase; cloud cover in eighths; wind speed on the Beaufort Scale; and rain in classes None, Cloud or Mist, Periodic drizzle, Continuous drizzle [no heavier rain was encountered]). On 29 Aug. 2013, the tree was measured – height, height of hollow from which the YBG emerged, height of most frequent launch point of glides, diameter at breast height (Fig. 1) – with a clinometer and tape.

At Gilbey Forest, four Rose Gums were occupied by two groups of YBG (based on marked individuals: Group 1, three trees; Group 2, one tree)

Figure 1. 'Spirit Tree', a Rose Gum (*Eucalyptus grandis*) in Tumoulin Forest, so named for a gargoyle-like growth on the trunk.
Left – the tree was 43.5 m tall and 157.5 cm diameter at breast height. Right – the trunk hollow from which the Yellow-bellied Gliders emerged (indicated) was 19.5 m above ground. All photos are by John Winter.

Figure 2. One of four Rose Gums (*Eucalyptus grandis*) in Gilbey Forest in which Yellow-bellied Gliders denned and were observed as they emerged, with the den entrance (a typical spout entrance) indicated.

corresponding to the groups whose social behaviour was described in detail by Russell (1984). Gliders were observed only silhouetted against the sky as described by Russell (1984), and observations were often discontinued once the first glider or group of gliders had emerged in order to investigate behaviour elsewhere. Times were noted from an analogue watch frequently standardised against radio broadcast times, and are likely to be accurate to within two minutes.

In the miscellaneous set, the technique was the same as at Spirit Tree except not necessarily extended beyond the first emergence and weather conditions were not consistently recorded.

Data analysis

For all observations, the time of Sunset and End of Civil Twilight was identified from the Geoscience Australia web-site (*https://www.ga.gov.au/scientific-topics/astronomical*; accessed on various dates) using coordinates unique for each site. Civil Twilight is the first and brightest of three twilight phases and is defined as ending when the sun is 6^0 below the horizon. The Geoscience Australia web-site was also used to determine the time of Moonrise and Moonset for the Spirit Tree observations.

For the Spirit Tree set, we classified observations as being moonlit if the moon was above the horizon at the End of Civil Twilight, it was not a New Moon, and cloud cover was zero (the only evening that would otherwise have qualified as moonlit had complete cloud cover). Times relative to End of Civil Twilight of the first YBG to emerge on each evening were compared between moonlit and unlit evenings with the Mann-Whitney U-test to test for any difference.

For the Gilbey set, we examined time of first emergence relative to End of Civil Twilight for variation among the four seasons (a fixed effect), between glider groups (a random effect) and between den trees (a random effect nested in glider groups). The analysis was performed as a permutational Anova in Primer v6 with the Permanova add-on (Clarke & Gorley 2006; Anderson *et al.* 2008). The similarity of emergence times was described by Euclidean distance, the model was Type III (partial) with fixed effects summing to zero for mixed terms, and the 9999 permutations of residuals were calculated under a reduced model.

Data are means ± standard errors.

Results

Of thirteen YBG den entrances across twelve trees, twelve were spouts such as in Fig. 2. The exception was Spirit Tree, in which the entrance was a hole in the side of the main trunk (Fig. 1).

Spirit Tree

From 19 July to 27 Sept. 2013, three YBG emerged from Spirit Tree during 14 of 15 observation evenings, and two emerged on one evening. During 12 evenings from 29 Sept. to 14 Nov. 2013, no YBG were seen to emerge on ten, whilst two and one YBG emerged on one evening each with one of the two individuals on 24 Oct. believed to be a juvenile. On three non-emergence evenings, either one or two YBG were seen to arrive at the den during the observation period. On numerous subsequent evening observations over a number of years, no YBG have been observed emerging from the Spirit Tree den, but in Aug. 2015 and again in Sept. of that year a single Greater Glider (*Petauroides volans*) was observed to emerge from it at dusk.

The first observed emergence for each evening occurred from 2 minutes before to 14 minutes after End of Civil Twilight (3.6 after ± 1.17 min; Fig 3A). Where more than one emergence was recorded in an evening, final emergences were from zero to 11 minutes (4.1 ± 0.92) after the first and from one minute before to 25 minutes after End of Civil Twilight (7.1 after ± 1.78). There was no effect of moonlight on time of first emergence ($P = 0.88$; Fig. 3A). Non-emergence during the study period was not associated with rain on any occasion.

On three evenings at Spirit Tree, YBG were heard to give a gurgling call from within the den one or two minutes before the first individual emerged. On 29 Sept., an evening when no YBG were seen to emerge but two arrived without entering the den, a call was heard from within the den. On at least eight evenings one or more of the YBG gave a low 'whoo' call as it departed the tree. On most evenings YBG departed the den tree by gliding away very soon after emerging. However, on one occasion all three were observed to sit outside the den grooming and stripping bark from the tree, departing three, four and nine minutes respectively after emerging. On 23 Sept. one

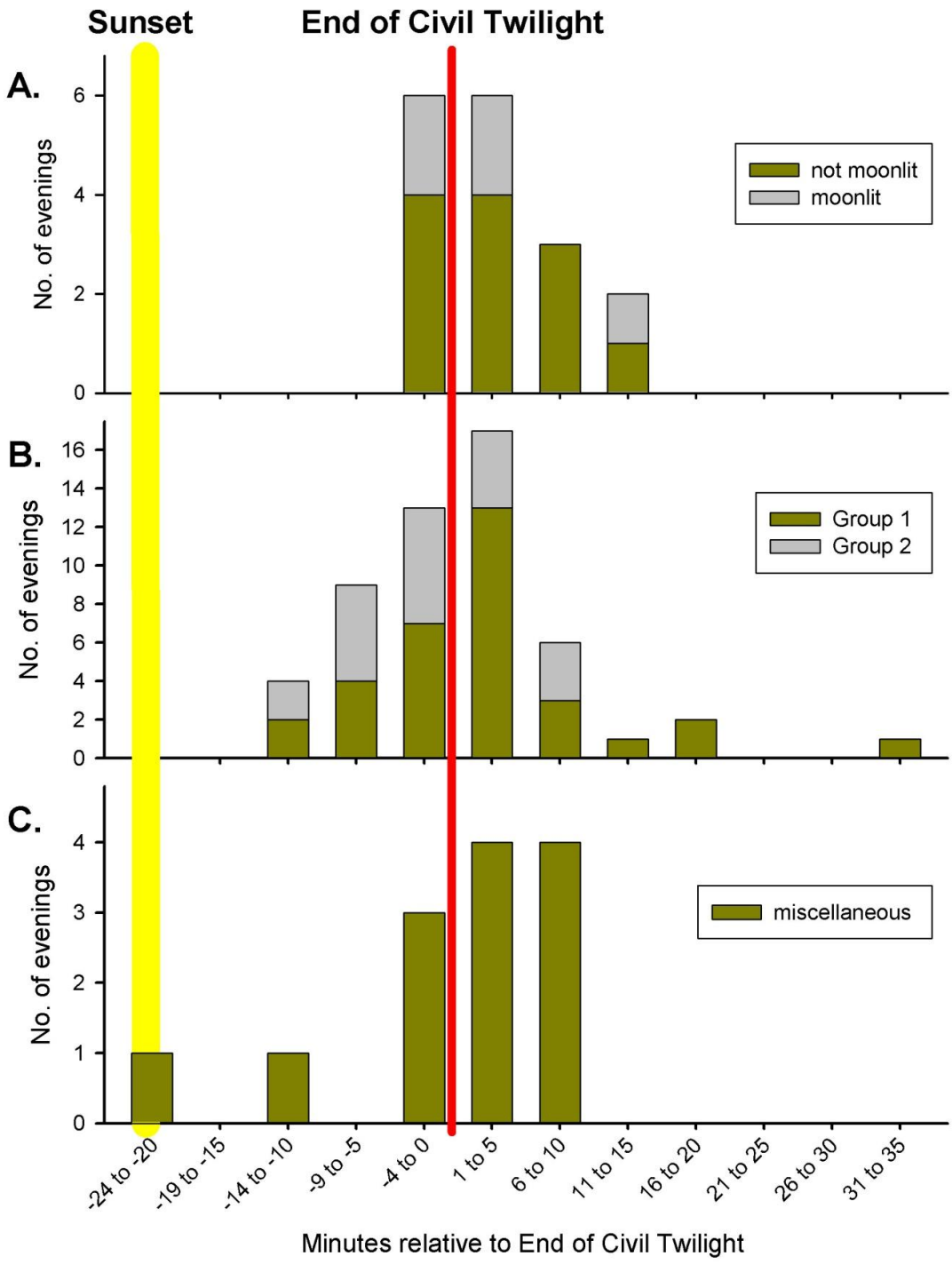

Figure 3. Time that the first Yellow-bellied Glider emerged relative to End of Civil Twilight from the Spirit Tree den (A), four dens in Gilbey Forest (B), and from seven other den trees (C).
The thickened line for Sunset is because it varied from 21 to 24 minutes prior to End of Civil Twilight.

lingered for 52 minutes around the den entrance before departing, and on 29 Sept. (the next observation) one lingered in the den entrance and had not departed when observation ceased 26 minutes later. On thirty of 37 individual emergences in which it was observed and recorded (81.1%), YBG climbed to a high point in the den tree before gliding away, the usual departure point being 31.9 m above ground (12.4 m above the den entrance; see Fig. 1). On the remaining seven occasions, YBG departed the den tree by gliding either directly from the den or from a nearby branch.

Other observations

In the Gilbey Forest set of observations, in which groups comprised from three to five individuals, time of first emergence ranged from 13 minutes before to 31 minutes after (0.8 after ± 1.11 min) End of Civil Twilight though most (83%) were from nine minutes before to eight minutes after (Fig. 3B). Time of first emergence relative to End of Civil Twilight did not vary with season ($P = 0.36$) nor between trees ($P = 0.62$), but varied strongly been YBG groups ($P < 0.0001$). Group 1 had a median emergence time of two minutes after End of Civil Twilight and Group 2 a median of three minutes before End of Civil Twilight. There was no obvious explanation (e.g. no heavy rain) for the outlying first emergence 31 minutes after End of Civil Twilight (Fig. 3B), when four YBG emerged together, and the only other observed emergence from the same den – 31 days later – occurred much earlier at 11 minutes before the End of Civil Twilight. Though not quantified, non-emergence from a den tree believed to be occupied is estimated to have occurred on less than 10% of evening observations.

In the thirteen additional observations which involved seven den trees, first emergence occurred from 22 minutes before to 10 minutes after End of Civil Twilight (0.6 after ± 2.40 min; Fig 3C), the extreme early emergence coinciding exactly with Sunset and not being associated with obviously unusual circumstances.

Discussion

The entrance to YBG dens are usually in spouts (e.g. Craig 1985) and were so in most cases in this study. The exception was a hole in the trunk (Fig. 1), a configuration that appears not to have been previously reported.

Yellow-bellied Gliders emerged from their dens in the early evening with mean times of emergence of between 0.6 and 3.6 minutes after End of Civil Twilight (mostly 15 to 35 minutes after Sunset). This is broadly as observed in previous studies of the species conducted in southern Australia; the same as reported by Craig (1985; usually within 30 min of Sunset) and a little earlier than reported by Goldingay (1989; mean 45.9 min after Sunset) and Lindenmayer *et al.* (1991; mean 19 min after Dusk – it isn't clear what is meant by Dusk). Kavanagh & Rohan-Jones (1982) reported that the first evening call of YBG, usually associated with their second glide shortly after emergence, occurred at a mean of 46.3 minutes after Sunset. Somewhat later emergence times might be anticipated in southern Australia as light fades from the evening sky more slowly – i.e. the interval between Sunset and absolute darkness is longer – in temperate than in tropical latitudes.

A necessary caveat to findings about timing in our and previous studies is that it is confounded by evenings on which no YBG emerged. Non-emergence could mean a failure to detect it because it occurred unusually early or late, or that the YBG had occupied an alternative den on that day. In north Queensland (Russell 1984; Goldingay & Quin 2004) as elsewhere (e.g. Henry & Craig 1984), YBG social groups periodically change den trees, as strongly inferred at Spirit Tree in this study. Whilst day-time activity is known only in sick YBG, the span of 53 minutes between the extremes observed in this study suggests the possibility that some routine first emergences might have been missed. However, the rate of non-emergence at the Gilbey Forest dens was low, suggesting that the general conclusion is robust.

Our observations suggest that the time of first emergence did not vary with presence/absence of moonlight or between seasons or trees, but to a small but significant extent between glider groups. The non-effect of moonlight occurred notwithstanding that YBG appear to be well within the weight range of prey taken by the co-occurring Rufous Owl (*Ninox rufa*) (Estbergs & Braithwaite 1985; Higgins 1999). YBG are occasional prey of the Powerful Owl (*N. strenua*) in southern Australia (Tilley 1982; Bilney 2013); Powerful Owls weigh about 20% more than a Rufous Owl (Higgins 1999) and southern YBG about 15% more than those from the Wet Tropics (JWW unpublished data). The difference in emergence times between groups might reflect differences within groups such as nervous temperament in lead individuals or variations in group size or breeding status. Additionally, environmental differences including resource availability that influences feeding imperatives, effects of position of dens such as aspect influencing exposure to light, or variations in foraging area could differentially affect emergence of groups.

We also documented some behaviours associated with emergence from dens including calls and

variation in activity at Spirit Tree that appeared to be related to the presence of a juvenile.

The 'whoo' call noted as YBG glided from den trees is as described by Russell (1984) and Goldingay (1994) and probably matches the "whirring moan" uttered occasionally when gliding as described by Kavanagh & Rohan-Jones (1982) and authors cited therein. However, the gurgling call heard to arise within the den has not been previously reported. It is assumed that the Spirit Tree den contained a young YBG for much of the observation period. One observation of a likely juvenile outside the den occurred later in the period when fewer YBG were using the den. Other behaviours observed at Spirit Tree later in the period included prolonged lingering at the den entrance and calling from within the den when no YBG emerged but two arrived without entering the den. Henry & Craig (1984) also documented changes in denning behaviour with development of young, with the female denning separately from group males when she was carrying a pouched young. This seems parallel to our observations. YBG usually raise a single young at a time (Goldingay & Jackson 2004). After *c.* 100 days in the pouch, young YBG live in the den for about 50 days before beginning to forage for themselves (Russell 1984). Our observation is therefore consistent with birth having taken place in about May or early June. In north Queensland, births can occur throughout the year but with a peak in winter (Russell 1984; Goldingay *et al.* 2001).

Yellow-bellied Gliders are intriguing mammals and the undescribed subspecies in north Queensland is seriously threatened (DERM 2011); on 9th July 2020 it was upgraded from Vulnerable to Endangered under the Commonwealth's EPBC Act (*https://www.environment.gov.au/node/49853*; viewed 20 July 2020). Much remains to be learned about them. Life inside dens is necessarily obscured to us without specialised equipment and intensive study, but we've documented interesting activity as they emerge for nocturnal foraging.

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